


Annual Dose Determination for Archeological and Geological Dating

T. Karali

Ege University, Institute of Nuclear Sciences, 35100
Bornova, Izmir, Turkey

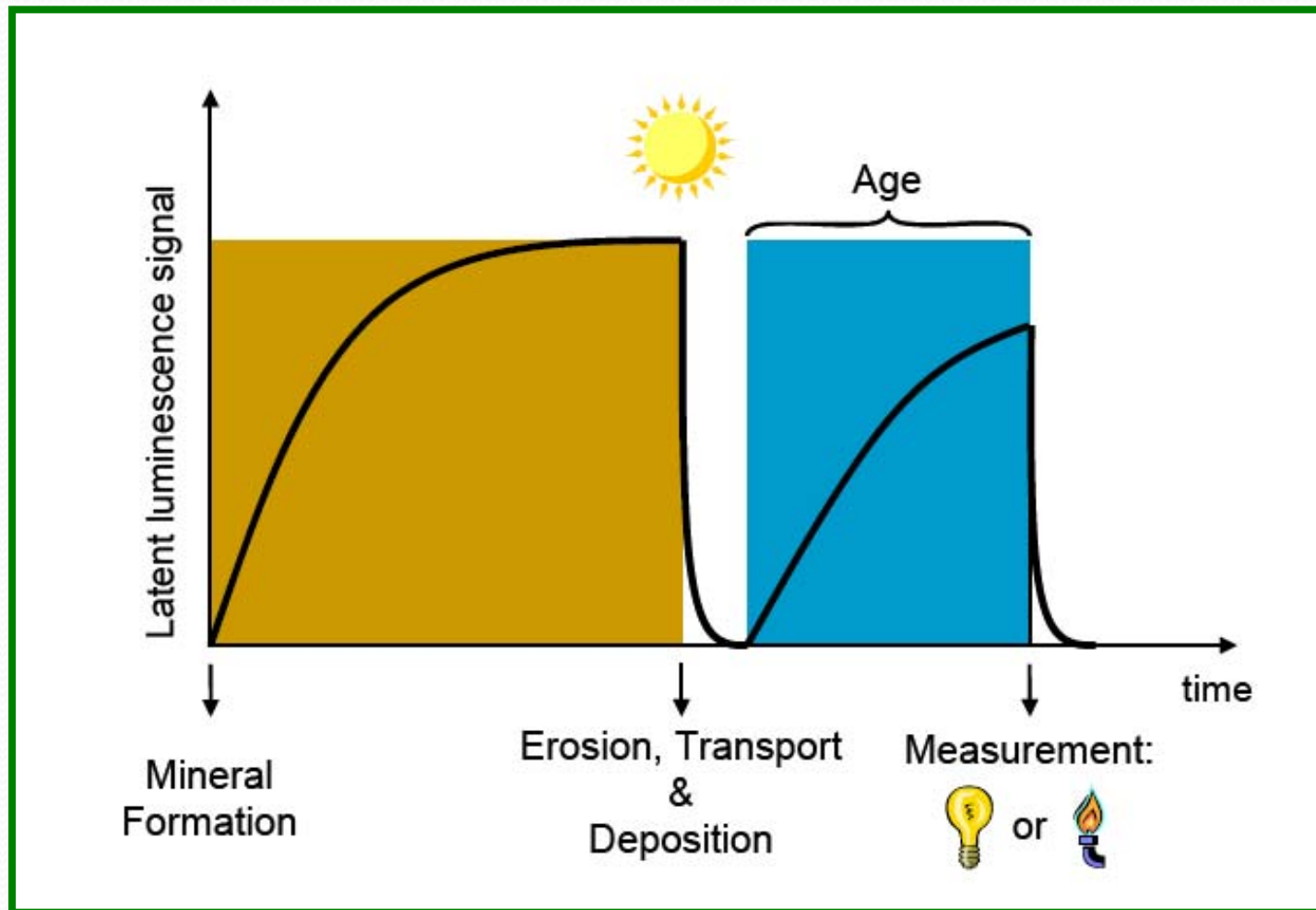
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- The annual dose refers to the rate at which the mineral grains in a sediment absorb energy from the surrounding flux of nuclear radiation in a year.
 - This radiation comes from the naturally occurring long-lived radionuclides ^{232}Th , ^{238}U , ^{235}U and their daughters, ^{40}K and ^{87}Rb , and from outer space. The decay of these radionuclides is attended with the emission of particles and photons.



Why do we need to determine the annual dose?

- Dating of ancient potteries for archeology
- Chronology of a geological site

Luminescence Dating



Annual Dose Determination

➤ Indirect Method:

by determining the concentrations of the naturally occurring radionuclides using gamma-ray spectroscopy plus cosmic rays.

➤ Direct Method:

using thermoluminescence detectors

e.g. $\text{CaSO}_4:\text{Dy}$, $\text{CaF}_2:\text{Dy}$, $\alpha\text{-Al}_2\text{O}_3:\text{C}$, etc.

➤ Indirect method

The soil samples were collected from Kaletepe region of Salihli for radioactivity analysis.



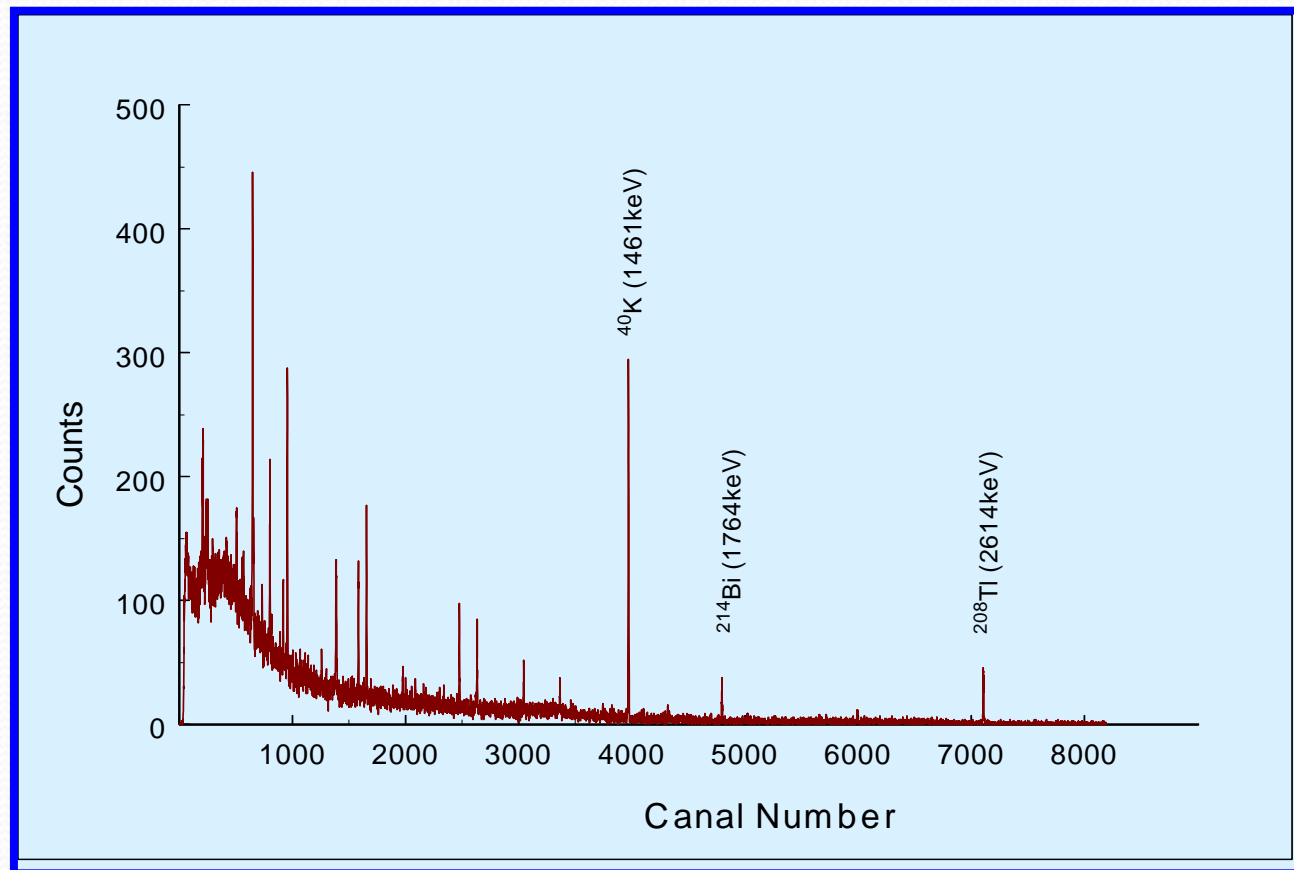
- Soil samples were dried at room temperature and sieved to eliminate any residues of plants. They (100 g) were sealed in polyethylene beakers. All samples were stored for more than 6 weeks to attain secular equilibrium between ^{226}Ra and its short-lived decay products.





➤ The activity concentrations of the natural radionuclides of soil samples, namely ^{238}U , ^{232}Th and ^{40}K were determined using a HPGe (Tennelec 184 cm^3 p-type coaxial) gamma spectrometer system.

Equivalent $^{238}\text{U} \rightarrow 1.76 \text{ MeV}$ gamma rays of ^{214}Bi
Equivalent $^{232}\text{Th} \rightarrow 2.62 \text{ MeV}$ gamma rays of ^{208}Tl
Percentage $^{40}\text{K} \rightarrow 1.46 \text{ MeV}$ gamma rays of its own.



Radioactivity Concentration of Soil samples

Sample ID	e Th (Bq/kg)	e U (Bq/kg)	%K (Bq/kg)
Kale1	29±4	32±5	505±50
Kale 2	24±3	19±5	382±50



➤ Gamma (D_γ) and beta doses (D_β) are calculated using the radioactivity concentrations (Bq/kg)

$$D_\gamma = 0,79 * K + 12,69 * Th + 8,98 * U \quad [\mu\text{Gy/y}]$$

$$D_\beta = 2,68 * K + 7,06 * Th + 11,42 * U \quad [\mu\text{Gy/y}]$$

(Aitken 1985)

Annual Dose Values Determined by Indirect Method

Sample ID	D_{γ} (mGy/y)	D_{β} (mGy/y)
1	$1,05 \pm 0,25$	$1,92 \pm 0,46$
2	$0,78 \pm 0,26$	$1,41 \pm 0,47$

→ Direct method

Direct method



Thick Al₂O₃:C TL dosimeters which are known to be very sensitive to radiation were used to determine D_{γ} and D_{cosmic} contribution to the annual dose.

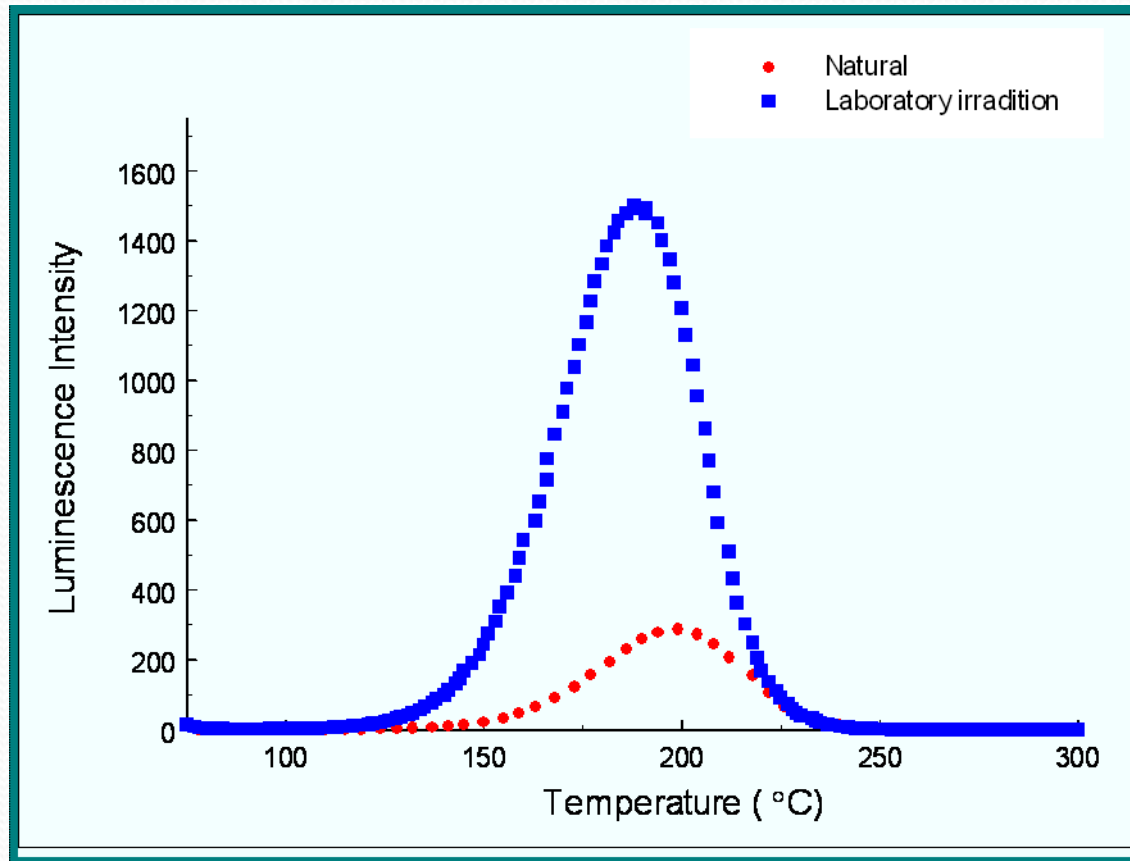
Al₂O₃:C TL



Dosimeters were covered by aluminum folia and placed in a small plastic tube, they were buried to sampling area and left there for a year or 6 months



After taking out the dosimeters, thermoluminescence glow curves were recorded using Harshaw TLD 3500 Reader.

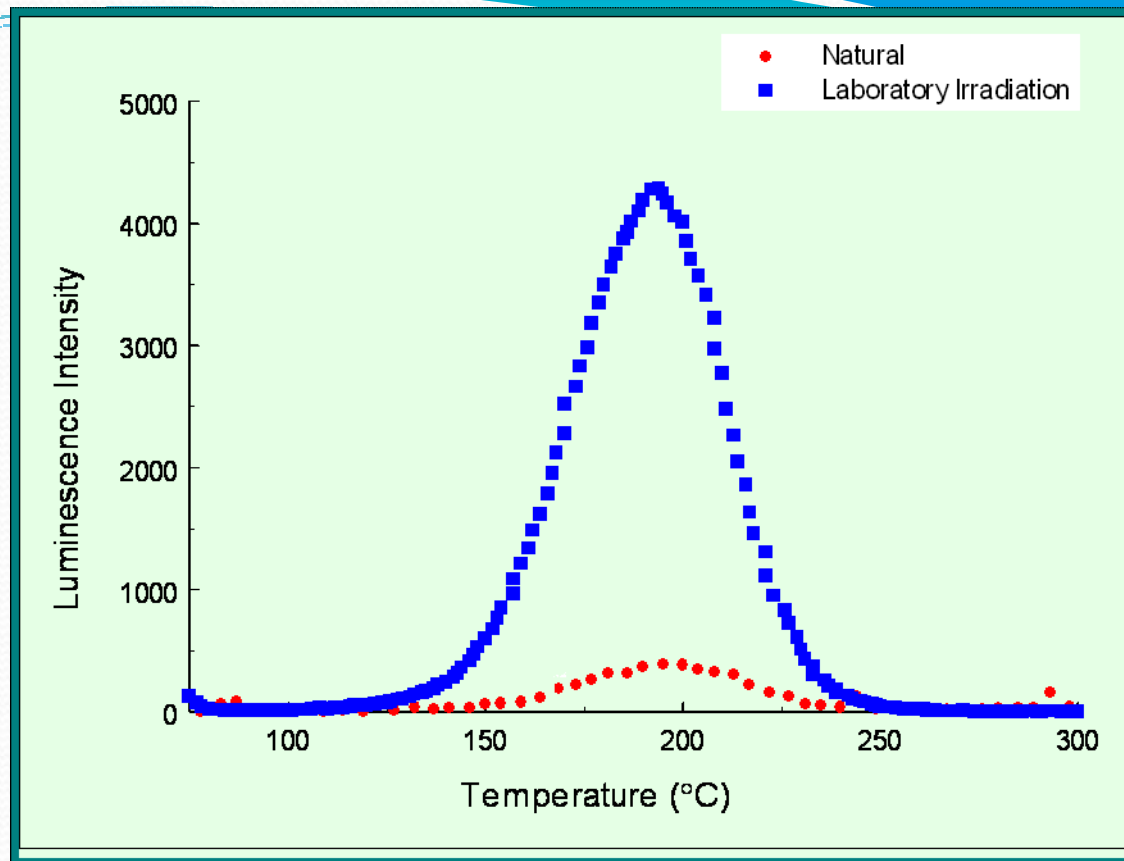


Gamma and cosmic contribution of annual dose were calculated by comparing natural dose with laboratory irradiation by Sr-90 (625 MBq).

Beta Contribution (D_β) of Annual Dose




Thin $\text{Al}_2\text{O}_3:\text{C}$ dosimeters were placed above sediments collected from sampling area for beta contribution of annual dose and subtracted quartz samples for background measurement.



After keeping the prepared samples in a 10 cm thick lead chamber for about 8 weeks in order to shield against gamma rays, glow curves were recorded by using TLD reader. Beta contributions of annual dose were calculated using these curves.

Annual Dose by Direct Method

Sample ID	$D_{\gamma} + D_{\text{cosmic}}$ (mGy/y)	D_{β} (mGy/y)
1	$1,38 \pm 0,06$	$2,12 \pm 0,26$
2	$1,06 \pm 0,09$	$1,42 \pm 0,16$



Sample ID	Direct (mGy/y)	Indirect (mGy/y)
1	3,50±0,42	3,27±0,50
2	2,48 ±0,30	2,49±0,37

Cosmic dose contribution to annual dose in the indirect method was assumed as 0,30 mGy/y
(*McKeever S.W.S., 1985*)



References

- *Aitken, M.J., 1985. Thermoluminescence Dating. Academic Press, London.*
- *Choi J.H., Murray A.S., Jain M., Cheong S.H. and Chang H.W., 2003. Luminescence dating of well-sorted marine terrace sediments on the southeastern coast of Korea. Quaternary Science Reviews, 22, 407-421.*
- *Zimmerman D.W., 1971. Thermoluminescence dating using fine grains from pottery. Archaeometry, 13, 29-52.*
- *McKeever S.W.S., 1985. Thermoluminescence of solids. Cambridge University Press, London.*
- *Murray, A.S., Wintle, A.G., 2000. Luminescence dating of quartz using an improved single aliquot regenerative dose protocol. Radiation Measurements, 32, 57-73.*
- *Prescott, J. R., Robertson, G. B., 1997. Sediment dating by luminescence: a review. Radiation Measurements, 27, 893-922.*
- *Fleming S.J., 1970. Thermoluminescence dating: refinement of the quartz inclusion method. Archaeometry, 12, 133-145.*
- *McKeever S.W.S., 1984. Thermoluminescence in quartz and silica. Radiation Protection dosimetry, 8, 81-98.*